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WI-CERFP RESPIRATORY PROTECTION OPTIMIZATION: A DETAILED ANALYSIS

By

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ABSTRACT

Each member of the Wisconsin Chemical Biological Radiological Nuclear and High-Yield Explosives Enhanced Response Force Package (WI-CERFP) is currently assigned a standard IRT Promask 2000 Powered Air Purifying (PAPR) system. Every member of the military, including the CERFP, is also assigned an Avon M50 Air Purifying Respirator (APR). In the event a non-CERFP member is called upon to assist with a CERFP mission, the only respiratory protection available is the Avon M50 APR. This research answers, "How does the Avon M50 APR compare to the Promask 2000 APR/PAPR and what is the recommended respiratory protection for the WI-CERFP?" The evaluation framework was used to compare the respiratory protection available to determine the best configuration based on matching the capabilities of the protection with the expected hazards. It was determined that hazards are different based on the zones of operation when responding to a natural or manmade disaster and different respirator types are best depending on the specific zone. The Avon M50 APR is the preferred escape respirator for any personnel not actively engaged in a hazardous environment, while the IRT Promask PAPR is preferred in areas containing airborne hazards not immediately dangerous to life and health. During the course of this research, it was discovered that the IRT Promask PAPR system has a high level of testing failure, posing great risk to personnel relying upon the respirator for continued health and safety. As a result, further research was performed, discovering an alternate Avon M53A1 respirator which can accept a PAPR for the same increased protection within the hazard zone. The final recommendation is to pursue the Avon M53A1 APR/PAPR as a replacement for the Avon M50 APR and IRT Promask 2000 PAPR system for the greatest level of safety, efficiency, and cost savings.

INTRODUCTION

When disaster strikes and overwhelms the local emergency responders in Wisconsin (WI), the WI National Guard Chemical, Biological, Radiological, Nuclear and High-Yield Explosive (CBRNE) Enhanced Response Force Package (CERFP) can deploy within six hours to assist. The WI-CERFP is trained to extract victims from rubble and unstable or collapsed structures while working in a hazardous environment. The WI-CERFP decontamination element can remove contaminants from casualties, and the medical element can treat, stabilize, and prepare victims for transport to the next level of care.

Two hundred and three personnel are part of the WI-CERFP and each is assigned a respiratory protection ensemble consisting of an IRT Promask 2000 Powered Air Purifying Respirator (PAPR) system.[1] Each person receives the same equipment regardless of position or purpose on the WI-CERFP. The 203 staffed positions are considered to be a minimum number necessary to fulfill the mission requirements; however, mission requirements can be as varied as man or nature can produce.[2] Situations may include an overturned railcar wafting anhydrous ammonia throughout a town, a tornado rolling through a chemical plant, or multiple dirty bombs exploding in a stadium. The plan is for the WI-CERFP to pull available resources and alternates such as physicians or administrative personnel to augment the CERFP until assistance from a neighboring state can arrive.

The primary problem needing to be addressed, is that any additional personnel and identified alternates for personnel on the manning document do not have CERFP assigned respiratory personal protective equipment. In the cold zone, personnel are not required to

[1] Department of Defense National Guard Bureau, "Homeland Response Force Chemical, Biological, Radiological, Nuclear, and High-Yield Explosives Enhanced Response Force Package Concept of Operation", 14 Oct 2015.
[2] Ibid.

actively wear any respiratory protection; however, an APR must be readily available as an escape mask in the event environmental conditions change. It is unacceptable to place CERFP alternates and additional responders in potential harm's way, so a solution must be found.

Every person in the military, including those who are part of the CERFP, is assigned an Avon M50 Air Purifying Respirator (APR). This research paper explores whether the Avon M50 APR can be used as an alternative to the IRT Promask 2000 APR. If the Avon M50 APR is approved for additional responders, this option should also be considered for any of the regular 203 WI-CERFP members whose duties will never require them to enter the hot zone. If the Avon M50 APR is a valid alternative to the IRT Promask 2000 APR, significant savings may exist without endangering or diminishing the mission in any way by appropriately configuring the PPE to the expected threat. This research answers, "How does the Avon M50 APR compare with the IRT Promask 2000 APR/PAPR and what is the recommended respiratory protection for the WI-CERFP?"

This research paper follows the evaluation framework.[3] First, an in-depth review of respiratory protection will take place to understand the difference between a PAPR and an APR and under which circumstances each would be desired. The individual elements of the WI-CERFP are examined as well as their hazards to convey a deeper understanding of the level of respiratory protection required. The technical data of the Avon M50 APR is compared to the IRT Promask 2000 APR to show how the M50 is a valid replacement for personnel in the cold zone. The evaluation includes performance data such as fit testing pass rates, chemicals, and breakthrough times as primary factors. Secondary factors are cost and time to maintain the

[3] Ackerman, John T., Matthew Stafford, and Thomas Williams. "Six Research Frameworks", 2010.

systems, space considerations, and additional training needed. The Occupational Safety and Health Administration (OSHA), Air Force, Army, and National Guard Bureau requirements are reviewed to ensure compliance with regulatory restrictions in a CBRNE environment. Finally, a recommendation will be provided for the WI-CERFP, and if accepted, can be applicable to all National Guard CERFPs.

RESPIRATORY PROTECTION

Theory of Respiratory Protection

Chemical routes of entry into a body can be through inhalation, injection, ingestion, or absorption. When a chemical is inhaled, the chemical can be absorbed into the blood stream via the lungs, or cause direct damage to the linings of the nose, throat, pharynx, trachea or lungs. Respiratory protection specifically addresses the inhalation route of exposure by protecting the respiratory systems. Respiratory protection is commonly achieved by either breathing a clean supplied source of air, such as through a Self-Contained Breathing Apparatus (SCBA) or through filtration of contaminated air by a media cartridge in the case of an APR.

Air Purifying Respirator - Detailed Configuration

An APR is typically either a full mask or half mask. A full mask APR consists of a sealed mask around the entire facial area of an individual, whereas a half mask seals around the nose and mouth only. In both cases, the contaminated air passes through a filtering media cartridge as the individual inhales, producing negative pressure. The flow of the contaminated air through the cartridge results in a less hazardous atmosphere within the mask. The media cartridges can be designed to filter specific chemicals or families of chemicals. The media cartridges can also be as simple as a filter designed to trap particulates if that is the hazard of

concern. The critical item is to match the cartridge and type of APR with the expected hazard by proper characterization of the breathing atmosphere.

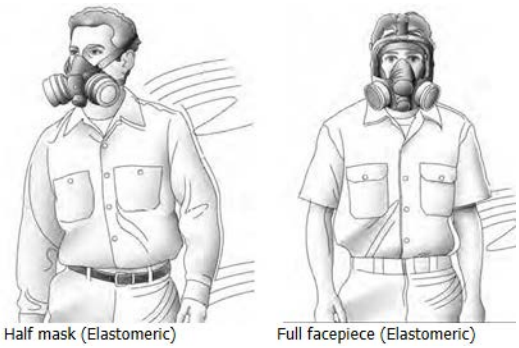

Figure 1: Examples of Air Purifying Respirators (APR) *(reprinted from 10 CFR 1910.134 - Respiratory protection", 2012, 428)*

Powered Air Purifying Respirator - Detailed Configuration

10 CFR 20.1003 defines a PAPR as, "an air-purifying respirator that uses a blower to force the ambient air through air-purifying elements to the inlet covering."[4] The blower unit is worn on the individual and forces air at a defined flow rate through the media cartridges and into a sealing mask. Essentially, the difference between the APR and the PAPR is "P" for power. The PAPR system forcing air provides positive pressure and is less dependent on the seal between the mask and face. This raises the effectiveness of the mask. In addition, the blowing air provides a cooling effect to provide greater comfort in warm conditions.

[4] United States Department of Labor, Occupational Safety & Health Administration, "29 CFR 1910.134 Respiratory Protection", www.osha.gov. Accessed 28 Nov 2015.

Figure 2: Powered Air Purifying Respirator (PAPR) (*reprinted from Osha.gov, "Assigned Protection Factors for the Revised Respiratory Protection Standard", 2009*)

WI-CERFP MISSION DESCRIPTION AND HAZARDS

WI-CERFP Mission Expectations

The mission of the WI-CERFP is to serve a civilian incident commander and augment any existing emergency responders with search and extraction, mass casualty decontamination, fatality collection, command, communication, and medical capabilities.[5] The WI-CERFP is comprised of 203 Army and Air Force National Guard members uniquely trained for CBRNE events and the Incident Command System (ICS) in addition to their assigned Military Occupational Specialty (MOS) or Air Force Specialty Code (AFSC). The WI-CERFP responds in Title 32 Active Duty or State Active Duty as directed by the Governor within six hours of notification.[6]

[5] Department of Defense National Guard Bureau, "Homeland Response Force Chemical, Biological, Radiological, Nuclear, and High-Yield Explosives Enhanced Response Force Package Concept of Operation", 14 Oct 2015.
[6] Departments of the Army and the Air Force National Guard Bureau, "National Guard Regulation 500-4/ ANGI 10-2504, Emergency Employment of Army and Other Resources, National Guard CBRNE Enhanced Response Force Package Management", 16 OCT 2009. 2.

In addition to responding within six hours, the WI-CERFP can be recalled and activated in a no-notice hazard capacity.[7] This is when the WI-CERFP is activated and pre-positioned along with local emergency responders near a threat area in response to intelligence stating the presence of an impending disaster or higher probability of terrorist attacks. Examples are political rallies, protests, high profile marathons, movement of large quantities of hazardous materials, or natural disasters with warning such as hurricanes. The WI-CERPF is expected to be able to respond and assist the incident commander in CBRNE environments, but not all elements of the CERFP will have exposure to hazards during normal operations.

Zones of Operation – Hot, Warm, and Cold

A CBRNE response environment is divided into three zones called the hot, warm, and cold zones. The hot zone is the area containing the hazard or potential hazard.[8] Typically, this is where the source of the hazard is found such as ground zero of a detonation, or a leaking chemical drum. It can also be the target area of an airborne release, or the entire area of a plume. In the hot zone, personnel must be adequately protected to carry out their essential work functions or provide rescue operations. The cold zone is the area completely free of the hazard where staging, command, and other support functions reside, along with the rest of the surrounding population. The warm zone is the controlled area between the hot zone and cold zones where efforts are made to limit the spread of contaminants from the hot zone into the cold zone through decontamination operations. Figure 3 below shows conceptually the hot zone (red) around the hazard source, followed by the warm zone (yellow), with the cold zone (green)

[7] Ibid.
[8] United States Environmental Protection Agency, "Safety Zones", http://www2.epa.gov/emergency-response/safety-zones, accessed 12 OCT 2015.

making up the rest of the area with no real boundaries. The size of the hot zone depends on the amount and type of hazard present as well as terrain and weather considerations.

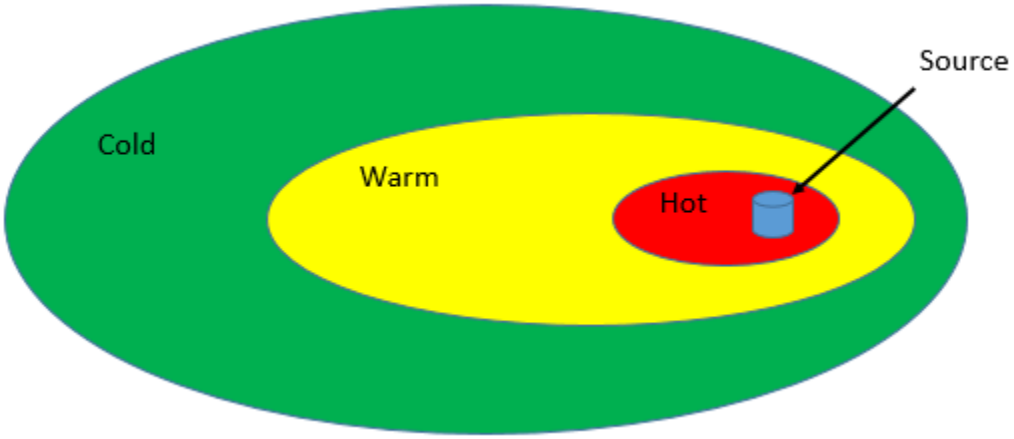

Figure 3: Hazard Zones

Hot Zone Respiratory Hazards

The focus of this research is protection against respiratory hazards. These are typically airborne, volatile hazards, but may also be particulate in nature. Particles may be heavy dust, asbestos, or contamination containing radioactive materials. In all these cases, efforts must be made to prevent inhalation of the hazard to prevent subsequent harm to the members of the WI-CERFP.

Search and Extraction (S&E), Fatality Search and Recovery Team (FSRT), and Hot Zone Triage are three groups with primary responsibilities within the hot zone. S&E teams are those who are entering into the hot zone searching for and extracting casualties. This group requires the highest level of Personal Protective Equipment (PPE) due to the hazardous environment and potential to encounter higher chemical concentrations in low elevation areas or confined spaces. A medical team member is part of each S&E group and performs initial stabilization and assessment, having direct contact with contaminated casualties. FSRT is tasked with collecting

people who have expired. Casualties quite often have higher concentrations of hazardous substances if exposure is the cause of death. Due to the FSRT operation requiring direct contact with casualties, and being in close proximity to the location of death, the potential risk of exposure for FSRT is high. The hot zone triage team assesses casualties delivered by the S&E teams to assist in directing them toward the appropriate decontamination line and medical care. The hot zone triage team consists of medical personnel and may need to conduct lifesaving or stabilizing measures prior to entering the decontamination area. The hot zone triage team is within the hazardous environment.

Warm Zone Respiratory Hazards

The decontamination element is the single group with primary responsibilities within the warm zone. The function of the decontamination team is to remove contaminants from CERFP personnel, equipment, and patients as they are retrieved from the hot zone. At the start of the operation, the decontamination team sets up their equipment in the cold zone, just outside the hot zone. As patients move through the decontamination line, contaminants are removed, gradually contaminating the area. The sources of any airborne hazards are brought in on the patients which may be present on skin and clothing. The personnel closest to the hot zone will be exposed to a higher level of contaminant and the concentration will progressively decrease as the patients move through the decontamination line. The level of respiratory hazard is lower than the hot zone, but may still be present.

Cold Zone Respiratory Hazards

The cold zone will not have any known hazards present. The groups with primary responsibilities within the cold zone are Cold Zone Triage, Green Medical Tent, Red/Yellow Medical Tent, Rehab, Bioenvironmental Engineering, Public Health, Logistics/Supply,

Communications, the individual element commands, and the primary Command and Control (C2) for the CERFP. Cold Zone Triage performs the same functions as Hot Zone Triage after the patient has been decontaminated. Green Medical Tent treats non-life threatening injuries of ambulatory patients. The Red/Yellow Medical Tent treats non-ambulatory patients and serious injuries of ambulatory patients. Rehab is an area set up to evaluate all of the CERFP team members when they exit the hot zone to verify they are not experiencing adverse effects from being in the hazmat suits or having any symptoms of chemical exposure. Bioenvironmental Engineering and Public Health comprise the preventive medicine group, monitoring food conditions, heat/cold concerns, and advise about occupational threats. Logistics/Supply provide equipment and supplies as needed, Joint Incident Site Communications Capability (JISCC) set up the network and connectivity not only within the CERFP operations zone, but also to ensure communication exists with external support groups and command. The element commands of all previously discussed groups are set up to monitor, coordinate, and control their individual operations. Primary CERFP C2 provides the overall control of the CERFP and is the link to the Incident Commander.

Cold zone elements are not designed to function any place except the cold zone, primarily because patients must be decontaminated prior to release or transportation to medical facilities. The greatest risk of an airborne hazard to those in the cold zone comes from an extreme change in wind direction affecting the direction of a plume of a known airborne hazard, or the presence of an undetected airborne hazard. If this occurs, personnel will need respiratory protection that can be quickly donned to evacuate to a new cold zone to reestablish operations.

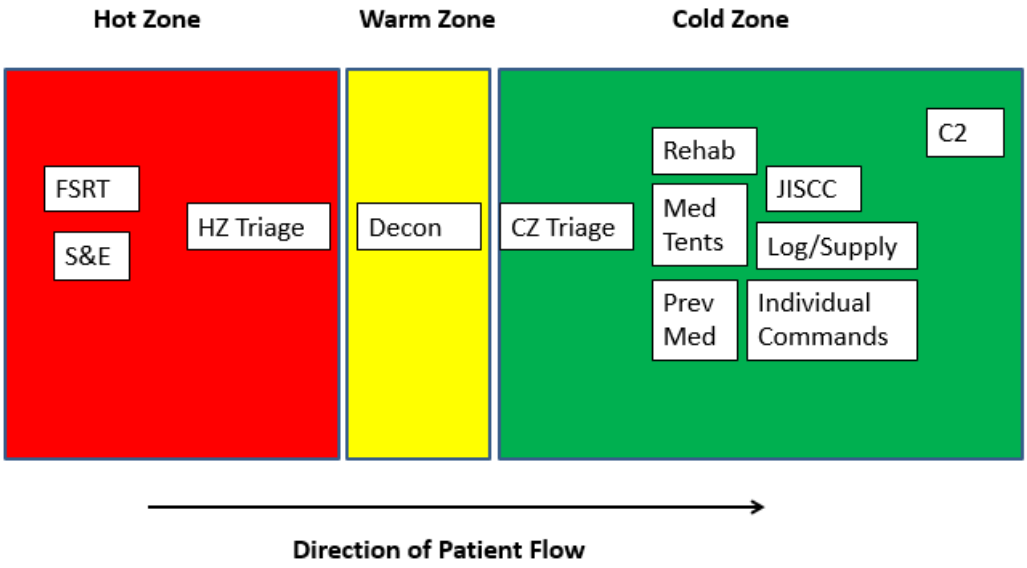

Figure 4: Locations of CERFP Elements within the Hazard Zones

WI-CERFP RESPIRATORY PROTECTION REQUIREMENTS

WI-CERFP Mask System - Current Authorization

The WI-CERFP has purchased a full IRT Promask 2000 PAPR/APR System for each of the 203 people on the manning document. This is the only system currently authorized, and the quantity purchased cannot exceed personnel on the manning document.[9] The system consists of an IRT Promask 2000 full-face mask, the PAPR blower pack, connecting hoses, batteries, air flow calibrator, rain covers, drinking adaptor, and a hard case to hold the entire ensemble. The cartridge authorized for purchase is the Cap 1 cartridge.[10] Cartridges can be directly connected to the mask making it an APR or configured to route the air through an external pump turning it into a PAPR.

[9] Evan Gilbertson, MSgt, WI ANG, Medical Logistics NCOIC WI CERFP.
[10] Ibid.

Each CERFP member, along with every person in the Air Force and Army, is also issued an Avon M50 Joint Services General Purpose APR mask equipped with an M61 canister. The M50 mask was developed specifically for the military to use within a CBRNE environment. These masks typically remain in storage with each individual's mobility deployment bag.

Respiratory Protection Program Requirements

The WI-CERFP respiratory program must comply with requirements defined by the Departments of the Army and the Air Force National Guard Bureau and any additional requirements imposed by the regulations specific to the CERFP. The purpose for this in-depth review is to ensure that any final Respiratory Protection Program (RPP) recommendations for CERFP personnel in each zone are in full compliance with the required respiratory protection regulations.

The National Guard Bureau Homeland Response Force Chemical, Biological, Radiological, Nuclear, and High-Yield Explosives Enhance Response Force Package Concept of Operation regulation does not state the type or level of respiratory equipment required or specific protection required by each element. [11]

National Guard Regulation 500-4/ ANGI 10-2504, National Guard CBRNE Enhanced Response Force Package Management states several requirements for the RPP.[12] NGR 500-4 specifies that a RPP will be established in accordance with 29 CFR 1910.134 "that provides a comprehensive testing or PAPR fit in compliance with OSHA Respiratory Protection Standards."[13] NGR 500-4 establishes this requirement for only those personnel required to wear

[11] Department of Defense National Guard Bureau, "Homeland Response Force Chemical, Biological, Radiological, Nuclear, and High-yield Explosives Enhanced Response Force Package Concept of Operation", 14 Oct 2015.
[12] Departments of the Army and the Air Force National Guard Bureau, "National Guard Regulation 500-4/ ANGI 10-2504, Emergency Employment of Army and Other Resources, National Guard CBRNE Enhanced Response Force Package Management", 16 OCT 2009.
[13] Ibid., 21.

a PPAR "in the performance of their duties." NGR 500-4 also specifies that all CERFP personnel will be fit tested with their assigned PAPR in accordance with 29 CFR 1910.134 Appendix A. Finally, NGR 500-4 states that Army regulations, Air Force regulations, and any local or state regulations are to be followed if stricter than 29 CFR 1910.134. A reference to general PPE is that adequate PPE includes protecting the respiratory system. The Appendix of NGR 500-4 states several additional 29 CFR respiratory protection documents which will be reviewed. NGR 500-4 states that CERFP personnel are to wear a PAPR if their duty requires it, and if it does, each must be assigned their own PAPR system, successfully pass a fit test, and follow the guidance set in 29 CFR 1910.134 to manage the RPP program. Fit test results must be recorded and maintained with the CERFP Mission Health records.

AFOSH Std 48-137 is the primary Air Force Instruction (AFI) defining the Respiratory Protection Program for the Air Force to include the Air National Guard.[14] It includes specific requirements for military respiratory protective devices used in Chemical Radiological Biological and Nuclear (CRBN) environments. The requirements within AFOSH Std 48-137 are based on the requirements from OSHA 29 CFR 1910.134 and state that if OSHA requirements change, then the changes must be followed. Several requirements in this AFI are applicable to this research paper and the WI-CERFP. First, the AFI requires that a respirator be used when the hazards in the environment cannot be reduced below the Occupational or Environmental Exposure Limit (OEEL) and that the installation Bioenvironmental Engineer can require a respirator based on his or her professional opinion of the potential hazard of the environment. The AFI also states that when in an emergency situation, escape-only respirators may be used. The Bioenvironmental Engineer is, "the authority for determining if respiratory protection is

[14] Department of the Air Force, "Air Force Instruction 48-137: Respiratory Protection Program", 15 JUL 2014.

required"[15] and must comply with 29 CFR 1910.134. In the case of military unique operations, OSHA standards do not apply, NIOSH-certified respirators are not required, and enrollment in the base RPP is not required. The Avon M-50 mask is an example of a CBRN mask typically used in a military unique operation with a provided example of home station defense during a CBRN event. For comparison purposes, Assigned Protection Factors do not apply to respirators used solely for escape and refers to 29 CFR 1910 subpart Z. This AFI includes guidance for selection of respirators intended for escape-only conditions. If there is a long distance to the exit or obstacles in the way, with no oxygen deficiency, the type of respirator is "Any air-purifying respirator." This is the applicable condition for personnel in the cold zone.

Army Regulation 11-34 is the regulation that defines the RPP for the Army to include the Army National Guard.[16] Like AFOSH Std 48-137, AR 11-34 takes its guidance from 29 CFR 1910.134. AR 11-34 requires the procurement of respirators approved by NIOSH; however, it also states that military unique masks and CBRN respirators are exempt from NIOSH approval and refers to DA Pam 385-61 for specific information. AR 11-34 adds that respirators used for emergency response are exempt from this regulation, but it does not clarify what an "emergency response" indicates. Army personnel required to use a respirator must undergo an annual medical evaluation following the requirements of 29 CFR 1910.134. There are no clear exceptions in this regulation for bypassing the annual medical evaluation if the only respirator to be used is an escape mask.

DA Pam 385-61 is the pamphlet called out in AR 11-34 with more specific information about military unique masks and CBRN respirators.[17] Within DA Pam 385-61 are criteria for

[15] Ibid., 8.
[16] Headquarters, Department of the Army, "Army Regulation 11-34: The Army Respiratory Protection Program", 25 JUL 2013.
[17] Headquarters, Department of the Army, "Pamphlet 385-61: Toxic Chemical Agent Safety Standards", 13 Nov

respirators that are used only for emergency escape purposes. The guidance states to select a "respirator for the atmosphere in which it will be used."[18] For chemical agent workers, respiratory protection must be NIOSH certified or Department of the Army-approved; however, there is specific reference to the M40 mask being approved for a maximum of 50 times the Short-Term Exposure Limit (STEL) for 15 minutes and being acceptable for escape purposes only. The Avon M50 mask is a replacement for the M40 mask.

29 CFR 1917.92: Retention of DOT markings, placards, and labels, 29 CFR 1915.154: Personal Protective Equipment (PPE) Standards for Shipyard Employment, 29 CFR 1918.102: Safety and Health Regulations for Longshoring, and 29 CFR 1926.103: Safety and Health Regulations for Construction, are all called out the appendix of NGB 500-4 and do not add pertinent information to this research.

29 CFR 1910.134 Occupational Safety and Health Standards Personal Protective Equipment Respiratory Protection is the primary regulation referenced by AFOSH 48-137 and AR 11-34. 29 CFR 1910.134 general requirements state that the employer must select a respirator based on the hazard and other factors that affect respirator performance. Additionally, the selected respirator must be NIOSH certified.[19] Immediately Dangerous to Life or Health (IDLH) atmosphere escape respirators are required to be NIOSH certified; however, the working atmospheres for the WI-CERFP are not IDLH which would require a greater level of protection than the provided PPAR system. 29 CFR 1910.134 does not provide obvious guidance about the requirements for a non-IDLH escape respirator, so OSHA released an advisory bulletin specific to CBRN Escape Respirators. At the time the bulletin was written, there were no NIOSH

2012.
[18] Ibid., 15.
[19] United States Department of Labor, Occupational Safety & Health Administration, "29 CFR 1910.134 Respiratory Protection", www.osha.gov. Accessed 28 Nov 2015.

approved APRs; however, government agencies were purchasing emergency escape masks specifically for potential CBRN environments.[20] OSHA did not object to or endorse this action, but instead sought to provide greater insight and understanding about NIOSH certification. NIOSH certification requires special testing for protection against 139 CBRN respiratory hazards. At the time the bulletin was released, many of the escape masks had only been tested for a few specific hazards, so the mask performance against the other test chemicals was unknown. Out of concern for employees, the emphasis fell upon the employers to properly understand the CBRN escape mask capabilities and evaluate against the potential airborne hazards. The critical point by OSHA is that a NIOSH approved respirator is required when working within a hazardous environment. A NIOSH approved respirator is desired, but not required when escaping from a hazardous environment as long as the atmosphere is not IDLH.

MASK CRITERIA AND LEVEL OF IMPORTANCE

Properties of the masks have been broken into "factors" to enable an easier comparison between the mask systems. Some of the properties are characteristics of the masks themselves, while others are pure financial or are related to the maintenance of owning each mask system.

Factor 1: Assigned Protection Factor

Respirator types have different degrees of effectiveness in hazardous environments. This degree of effectiveness is referred to as the Assigned Protection Factor (APF). Each chemical has a maximum concentration level where a person can work safely in the environment with no adverse effects. The maximum concentrations commonly used are the permissible exposure limit (PEL) and STEL; however, wearing a respirator allows a person to work in a hazardous

[20] United States Department of Labor, Occupational Safety & Health Administration, "CBRN Escape Respirators", www.osha.gov, Accessed 28 Nov 2015.

environment at levels higher than the exposure limits. The new exposure limit is called the Maximum Use Concentration (MUC) and is determined by multiplying the exposure limit by the APF.[21] For example, if a chemical's PEL is 5ppm and the respirator being used has an APF value of 10, the person can enter a hazardous environment up to 50ppm and expect the respirator to provide sufficient protection. A higher APF is more desirable because it potentially allows teams to enter areas containing higher levels of airborne hazards.

Factor 2: Canister Breakthrough Times and Type

Breakthrough occurs when a hazardous chemical "breaks through" the cartridge media from the external environment into the breathing space of the mask, causing the RPP system to fail. Breakthrough charts list the concentration of the chemical along with the time it takes to be detectable through the cartridge media. Higher breakthrough times, as well as a greater range of tested chemicals is more desirable. Achieving NIOSH certification refers partially to the mask and cartridge system being tested against a specific set of chemicals and achieving minimum breakthrough times. The type of canister available to the CERFP for the Promask 2000 APR/PAPR was provided by the National Guard CBRNE Account Manager.[22] The Avon M50 has only one canister option available.[23]

[21] United States Department of Labor, Occupational Safety & Health Administration, "29 CFR 1910.134 Respiratory Protection", www.osha.gov. Accessed 6 DEC 2015.
[22] Roger Watson, National Guard CmSupCen CBRNE Account Manager.
[23] Avon Protection, "M50" http://www.avon-protection.com/products/m50.htm, Accessed 14 Dec 2015.

Factor 3: Cost for Initial Purchase

The Avon M50 APR, IRT Promask 2000 APR and IRT Promask 2000 PAPR systems each have initial costs. The costs of the IRT Promask 2000 APR/PAPR were provided by the WI-CERFP Medical Logistics NCOIC who is directly responsible for purchasing equipment.[24] The cost of the Avon M50 was obtained from the Federal Logistics Information System Web Search (WebFLIS).[25] A lower initial cost is more desirable.

Factor 4: Cost for Wear Items

A wear item is a portion of the RPP system that is serviceable and periodically replaced due to wear or damage. Examples of wear items are batteries, inlet valves, drinking tubes, and the PAPR blower. The source of data for this section was provided by the WI-CERFP Medical Logistics NCOIC and 115FW Mobility.[26,27] The value was determined by adding the total cost of repair and wear items within 12 months and dividing by the number of masks to yield an average cost per mask. A lower cost of maintenance is more desirable.

Factor 5: Time to Maintain

This factor measures the amount of time to maintain the system to a proper level of readiness. It includes time to inventory, clean, inspect, charge batteries, and test air flow. The source of this data was direct measurement by the WI-CERFP Medical Logistics NCOIC who maintains the equipment.[28] If the Avon M50 APR were used on a regular basis, the time to maintain would be similar to the IRT Promask 2000 APR. A lower time to maintain the RPP system is more desirable.

[24] Evan Gilbertson, MSgt, WI ANG, Medical Logistics NCOIC WI CERFP.
[25] Federal Logistics Information System Web Search (WebFLIS), Accessed 14 Dec 2015.
[26] Evan Gilbertson, MSgt, WI ANG, Medical Logistics NCOIC WI CERFP.
[27] Scott Relitz, TSgt, 115FW LRS, Mobility/IPE
[28] Evan Gilbertson, MSgt, WI ANG, Medical Logistics NCOIC WI CERFP.

Factor 6: System Weight

The comparable weights of the Avon M50 APR, IRT Promask 2000 APR, and the PAPR addition for the Promask 2000 were reviewed. The weight of each system can contribute to personnel fatigue over time, and also adds to the cargo weight of the CERFP during transport. The sources of data for this factor were direct measurements by the WI-CERFP Medical Logistics NCOIC.[29] A lower system weight is more desirable.

Factor 7: Inventory - Storage Requirements

Storage space is important for bases where space is limited and affects cargo space of air or ground transport when traveling to the incident site. The sources of data for this factor were direct measurements by the WI-CERFP Medical Logistics NCOIC.[30] A smaller storage space requirement is more desirable.

Factor 8: Shelf-life

Shelf-life refers to any system components or the mask itself that will degrade in performance over time due to age. When an item has reach the end of its shelf life, it has expired and must be replaced. Items that require more frequent replenishment adds administrative requirements such as ordering new items, disposal of the old materials, and time to physically perform the swapping of items. Items with a shelf life also pose added risk of failure by missing an item that is expired. The sources of data for this factor were direct from the manufacturers of the respiratory systems.[31,32] A longer shelf-life is the more desirable condition.

[29] Ibid.
[30] Ibid.
[31] Immediate Response Technologies, http://www.imresponse.com, Accessed 14 Dec 2015.
[32] Jeff Hermanson, JSGPM Program Manager, Avon Protection Systems.

Factor 9: Temperature Limitations

Temperature is more likely to be a factor in colder response environments where the flexibility of the mask rubber is affected. Rubber that does not conform to facial features will compromise the mask seal and place the wearer at risk. Also, cold temperatures can decrease battery life, affecting the length of time response teams can be operational. Hot environments beyond the manufacturer's limitation can potentially cause overheating of the any mechanized components or contribute to permanent deformation of the mask rubber, which again would jeopardize the face seal. The sources of this data were direct from Avon and IRT. A greater useable temperature range, at minimum to include the typical range in Wisconsin in January through the hottest storage conditions is more desirable.

Factor 10: Power Requirements

The category of power requirements is specific to the PAPR system only. If power is lost on a PAPR, the system reverts to an APR along with the lower APF. If the MUC is acceptable with the PAPR in the hazardous atmosphere, but is not acceptable with an APR, the wearer is at risk. No power requirements is more desirable; however, if power is a requirement for the system, then it is more desirable to have a long operating life expectancy of the system, to exceed the response time-frame. The source of this data is IRT.

Factor 11: Fit Test Results

One of the requirements of the respiratory protection system is for each person to pass a fit test with his or her assigned mask. The fit test consists of the wearer donning the mask and performing a set series of tasks to include breathing, speaking, and various movements to evaluate if the mask seal is compromised during any of these activities. The fit test machine is physically connected to the mask and measures the air quality of the ambient air to the air quality

inside the mask. If the mask is performing, with an adequate seal, the air inside the mask is "cleaner". The output of the test is a ratio of dirty air to clean air, with a minimum value required to be considered passing the fit test.

This factor is divided into two sections: initial pass results with no assistance, and final pass results with assistance. The tester gathering data for this research was instructed to have the CERFP member don their mask with no assistance to simulate a real response. During a response, personnel must be able to don their PPE properly to be protected from the hazards. If the initial test result indicated a fail, the tester was instructed to assist personnel and troubleshoot the cause of the failure by correcting any errors such as hair caught in the mask sealing area, mask improperly positioned on their face, harness not centrally located, or straps not properly tightened with equal pressure. The initial test results are indicative of the overall "ease of use" of the mask and inherent variability in positioning that may occur with each donning of the mask in addition to any failures caused by a faulty mask.

The final fit test results are a measure of mask quality and not human error. For example, if the initial fit test fails, but the final test passes, the error lies with the person improperly donning the mask. If the initial fit tests and final fit tests fail, this indicates the mask itself is faulty. The faulty mask is confirmed by having personnel fit test on a known good mask of the same size. The source of this data is the Bioenvironmental Office at the 115FW.[33] High pass rates in both categories are more desirable. This is a critical factor to consider.

[33] 115FW fit test data gathered 12 Jan 2015 through 8 Nov 2015.

DATA RESULTS

Factor	Description	IRT Promask 2000 PAPR	IRT Promask 2000 APR	Avon M50 APR
1	Assigned Protection Factor	1000	50	50
2	Canisters available to CERFP/ General Military Population	Cap 1	Cap 1	M61
	NIOSH Certified	Yes	Yes	No, M61 Yes
3	Cost to Purchase New	$1,211.08	$378.51	$429.85
4	Cost of Wear Items	$58.26	$28.80	$0.83
	Cost of Canisters	$28.04	$28.04	$48.76
5	Time to Maintain - yearly total time (hr)	13.0	3.7	3.7
6	Weight (lb)	3.6	2.1	1.9
7	Size of Box (ft^3)	1.15	0.61	0.42
8	Shelf Life of Mask (yr)	20	20	10
	Shelf Life of Canisters (yr)	10	10	10
9	Operating/Storage Temperature Range (°F)	-26 - +120	-58 - +150	-13 - +160
10	Power Requirements (hr)	Battery 4+2inc	N/A	N/A
11	Fit Test Pass Rate - no tester assistance	48%	48%	99.4%
	Fit Test Pass Rate - with tester assistance	80%	80%	100%

Table 1: Data Results

Factor 1 shows a significant difference in APF between the PAPR and APR masks. The PAPR APF enables the wearer to operate in a chemical environment 20 times greater than the maximum safe concentration allowable with an APR. If needed based on the concentration of the hazard, the additional APF provides an added level of response flexibility for the WI-CERFP.

Factor 2 includes whether the mask and canister is NIOSH certified. The Promask 2000 PAPR and APR are NIOSH certified; however, the M50 APR is not. The primary reason M50 is not certified is due to the connection style of the canister to the mask, and not through any performance failure. The M50 canisters exceed NIOSH chemical testing requirements, providing the required level of protection, but the technicality of lacking the NIOSH stamp of approval makes using the Avon M50 APR mask questionable depending on regulation interpretation.

Reviewing the financial factors, the IRT Promask 2000 PAPR incurs a higher cost and time to main due to the added complexity and number of components in the system. The Avon M50 APR has a higher initial cost compared to the IRT Promask 2000 APR, but this is balanced by the lower cost of wear items.

Factor 11, Fit Test Pass Rates, show a significant difference between the IRT mask and the Avon mask. The interpretation of these numbers is that in an operational environment, the IRT mask fails over 50% of the time, while the Avon mask fails less than 1%. The Avon M50 APR initial failures were all corrected by changing the size of the mask, and not due to improper wear. A mask failure means the wearer can be exposed to a chemical hazard higher than predicted due to partial filtration, but also includes the possibility of a catastrophic mask failure resulting in full exposure to the hazardous chemical. Also of note, referring to the IRT mask failures, some of the failed masks were deemed "good" as a result of the prior year's annual testing, making the exact time of failure unknown during the year between "good" and the "bad" result. In addition, some of the IRT PAPR units failed while in use during readiness exercises even though the PAPR units passed inspection and air flow checks immediately prior to the start of the exercise. The failure modes included a decrease in airflow and also an instance of the PAPR unit blowing smoke into the wearers mask. When the PAPR fails, the system's APF rating drops from 1000 to 50 because a PAPR with no power effectively reverts to an APR. Recalling the importance of the APF in determining the acceptable operational chemical concentration personnel can safely work in, the wearer can suddenly be insufficiently protected for the environment if the PAPR blower unit fails.

Based on the data, there is no clear winner due to conflicting factors. The IRT Promask 2000 PAPR has the potential to be the top choice due to the higher AFP, but this is negated due

to the low fit test pass rate, blower failures while in use, and higher cost to purchase and maintain. Comparing the IRT Promask 2000 APR against the Avon M50 APR, the Avon M50 seems to be the clear choice due to the superior fit test pass rate, except it lacks the NIOSH certification.

RECOMMENDATIONS

Personnel in the hot zone should be authorized and wear a PAPR due to the higher APF, enabling responses in higher concentration environments. It is important to note that even with a PAPR, CERFP members can never enter an IDLH or oxygen deficient environment with this level of respiratory protection.

All personnel in the warm zone should not need a PAPR based on the low concentration of airborne hazards; however, the PAPR also provides cooling air for increased comfort. The decision to use a PAPR versus an APR should be based on the combination of environmental conditions and local air monitoring to calculate the MUC. Personnel in the warm zone should be authorized to wear a PAPR system as an option.

Personnel in the cold zone can be divided into two categories: those who are alternates to hot zone personnel, and those who are not alternates to hot zone personnel. Alternates to hot zone personnel should be assigned an APR compatible with the PAPR system. Each person does not need to incur the cost of an individually assigned PAPR add-on. They only need an individually assigned mask that has been verified to pass the fit test. CERFP members who are not alternates to personnel on hot zone teams do not need an APR compatible with a PAPR system. Personnel in the cold zone do not need to actively wear an APR due to the absence of

airborne hazards; however, an escape mask that can be quickly donned is recommended if environmental conditions, such as wind direction, rapidly shift. Because the atmosphere in the hot zone is not IDLH, the atmosphere requiring an escape mask during shifting conditions should also not be IDLH. The non-IDLH condition eliminates the NIOSH requirement. Also, if the WI-CERFP is deemed a "military unique operation", the NIOSH requirement does not apply.

The change that can be implemented immediately is outlined in Table 2, which specifically eliminates the need for all members of the WI-CERPF to be assigned a full IRT Promask 2000 PAPR system. Cold zone personnel do not need to be assigned any additional respiratory protection equipment beyond the existing Avon M50 APR assigned to all military. Cold zone people who are alternates to the hot zone need a mask compatible with a PAPR, but there is no need for a PAPR to be individually assigned. The PAPR can be considered additional equipment to be released from supply prior to use. The example cost savings are based on initial mask costs only with estimated personnel who fall into each category. The conservative assumption is that at least one person from each hot zone element remains in the cold zone in a liaison function. The medical element has operational responsibilities in the hot and cold zones. The savings in Table 2 also assume the medical element has assigned alternates to account for an unlikely 100% swap of personnel. The exact numbers of alternates and cold zone personnel should be determined based on the analysis of the elements by the CERFP commanders. The savings column does not include wear items, time saved by reduced maintenance, or space savings in inventory or while traveling.

	Old configuration	New configuration	Estimated Savings
Hot Zone	IRT Promask 2000 PAPR	IRT Promask 2000 PAPR	$0
Warm Zone	IRT Promask 2000 PAPR	IRT Promask 2000 PAPR	$0
Cold Zone Alternates to Hot Zone	IRT Promask 2000 PAPR	IRT Promask 2000 APR Only	$11,656
Cold Zone	IRT Promask 2000 PAPR	Avon M50 APR	$50,865
		Total	$62,521

Table 2: Immediate Recommendation

The immediate recommendation should not be considered to be the final recommendation for the WI-CERFP due to the poor fit test results. The primary concern for personnel is to ensure continued safety while responding to a disaster, which the IRT respiratory protection systems do not provide. One option is to address the quality issues with IRT, but there is a better option. Avon Protection recognizes the need for NIOSH approved APR and PAPR systems for the military. The primary reason the Avon M50 cannot be NIOSH certified is due to the double filter bayonet canister connection instead of the single 40mm thread configuration.[34] As a result, Avon is currently seeking NIOSH approval to supply a low-cost "upgrade" kit which will convert the bayonet style connection into the 40mm screw connection. In the event OSHA requires all escape masks to be NIOSH certified, and the WI-CERFP is not deemed a military unique operation, the $15 upgrade would be a valid alternative.

The best case scenario is to avoid the cost of an additional respiratory protection system beyond the standard issue military mask. Researching further, Avon has created the M53A1 APR mask which is identical to the M50 in all ways except the canister connection. The M53A1 APR was NIOSH certified September 2015. Due to the connection type of the M53A1, the Avon PAPR is an option. The PAPR has passed all NIOSH testing, with the final certification

[34] Jeff Hermanson, JSGPM Program Manager, Avon Protection Systems.

documents expected to be granted December, 2015. Avon is currently undergoing contract review with the military and is expected to be finalized in July of 2016, making the M53A1 APR and PAPR authorized to be purchased. What this means, is that instead of issuing the M50 mask to WI-CERFP personnel, they should be issued the M53A1. If the operational requirements demand a PAPR, the Avon PAPR can be purchased for this added capability. If the Avon PAPR cost is similar to the IRT PAPR costs, the savings to the WI-CERFP look like Table 3. The results are a minimum savings of $123K while providing a significant increase in safety with fit test results higher than 99%, and canisters that exceed NIOSH requirements.

	Old configuration	Optimal Configuration	Estimated Savings
Hot Zone	IRT Promask 2000 PAPR	Avon M53A1 PAPR add-on	$27,631
Warm Zone	IRT Promask 2000 PAPR	Avon M53A1 PAPR add-on	$28,010
Cold Zone Alternates to Hot Zone	IRT Promask 2000 PAPR	Avon M53A1 APR	$16,955
Cold Zone	IRT Promask 2000 PAPR	Avon M53A1 APR	$50,865
		Total	$123,461

Table 3: Optimal Configuration

Another benefit of the configuration outlined in Table 3 revolves around any personnel assisting the CERFP beyond the assigned 203 regular members such as additional medical, or public health, or administrative personnel. Under the old configuration, they do not have the assigned IRT Promask 2000 respiratory protection. Under the new configuration, they would use the Avon M50 APR or Avon M53A1 APR and be properly equipped for the hazards.

There are 17 CERFP units that fall under the Title-32 State Response heading and all are configured identically from a respiratory protection standpoint. If all CERFP units adopted the optimal configuration in Table 3, the cost savings in initial equipment alone would exceed $2 million with improved safety and reliability, lower maintenance costs, and lower maintenance time requirements for personnel.

BARRIERS TO RECOMMENDATIONS

A barrier to the immediate recommendation in Table 2 is the belief that NIOSH certified masks are required in the cold zone. This requirement is unclear and may or may not be required depending on interpretation. The highest priority is the safety of the CERFP members and looking at the reliability of the Avon M50 mask, this is the best option available today to keep people safe.

Another barrier to the immediate recommendation in Table 2 is the belief that all people regardless of operation zone need the full PAPR configuration. This is not true because medical personnel will not be stabilizing extracted personnel while in a contaminated environment. If the environment is contaminated, then so are the patients. Contaminated patients cannot be evacuated to medical facilities without first being decontaminated. This is the entire function of the decontamination element of the CERFP. So, in the event the cold zone becomes contaminated, the operation must be moved to a "new" cold zone and re-established. Cold zone personnel do not need a PAPR as part of their operational functions.

A barrier to Table 2 can also be the statement that the equipment is already purchased, so it should be used. Besides the equipment being faulty, requiring the use of equipment simply because it's owned is not a valid argument. Equipment usage should be optimized based on the needs of the operation. Requiring the use of an item not needed places an unnecessary burden on personnel time, cost to maintain, and training.

A barrier to Table 3 is that all military personnel currently have the Avon M50 APR and the additional cost associated with purchasing the Avon M53A1 required to enable the PAPR option can't be justified. The exact details of the contract currently being negotiated are not

known and may include the full replacement of the M50 with the M53A1 for all service branches. If this is not the case, then the M50 should be deemed obsolete, but still available to use with all new purchases to be the M53A1. As masks are destroyed or lost or deemed unfit for further use after deployments, the M50 mask will gradually be phased out simply due to attrition. Inventories of the M50 masks must be shifted to non-CERFP military branches, with the priority of new purchases falling to the CERFP. The next priority for replacement should be all units in the National Guard associated with the CERFP mission. Active duty and non-CERFP National Guard units should be lowest priority for the M50 replacement once all previous inventory requirements are fulfilled.

CONCLUSIONS

The Avon M50 APR is a valid substitution for the IRT Promask 2000 APR and is acceptable to use for additional responders and alternates to WI-CERFP. The overall current respiratory protection configuration requiring all members of the WI-CERFP to use the IRT Promask 2000 PAPR system is not optimized for greatest efficiency and safety based on the operational requirements of personnel. Immediate steps can be taken by replacing the IRT Promask 2000 PAPR system with the Avon M50 APR for select personnel in the cold zone, resulting in improved safety, time, and financial benefits. Through this research, a significant safety concern was discovered with the current IRT respiratory protection. An optimal configuration making use of the Avon M53A1 APR/PAPR will soon be available that will significantly raise the safety level of the WI-CERFP, providing even greater financial and efficiency improvements beyond the initial recommendation.

ACRONYMS

AFI – Air Force Instruction

AFSC - Air Force Specialty Code

ANG – Air National Guard

APR – Air Purifying Respirator

C2 – Command & Control

CBRN - Chemical Radiological Biological and Nuclear

CBRNE - Chemical Biological Radiological Nuclear and High-Yield Explosives

CERFP - Chemical Biological Radiological Nuclear and High-Yield Explosives Enhanced Response Force Package

CFR – Code of Federal Regulations

FSRT - Fatality Search and Recovery Team

ICS – Incident Command System

IDLH - Immediately Dangerous to Life or Health

JISCC - Joint Incident Site Communications Capability

MOS - Military Occupational Specialty

MUC - Maximum Use Concentration

NGB – National Guard Bureau

OEEL - Occupational or Environmental Exposure Limit

OSHA - Occupational Safety and Health Administration

PAPR – Powered Air Purifying Respirator

PPE – Personal Protective Equipment

RPP - Respiratory Protection Program

S&E – Search and Extraction

SCBA - Self-Contained Breathing Apparatus

STEL - Short-Term Exposure Limit

WebFLIS - Federal Logistics Information System Web Search

WI – Wisconsin

BIBLIOGRAPHY

Ackerman, John T., Matthew Stafford, and Thomas Williams. *Six Research Frameworks*. 2010.

Avon Protection, www.avon-protection.com.

Department of the Air Force. *Air Force Instruction 48-137: Respiratory Protection Program*. 15 JUL 2014.

Departments of the Army and the Air Force National Guard Bureau. *National Guard Regulation 500-4/ ANGI 10-2504, Emergency Employment of Army and Other Resources, National Guard CBRNE Enhanced Response Force Package Management*. 16 OCT 2009.

Department of Defense National Guard Bureau. *Homeland Response Force Chemical, Biological, Radiological, Nuclear, and High-yield Explosives Enhanced Response Force Package Concept of Operation.* 14 Oct 2015.

Gilbertson, Evan, MSgt, WI ANG, Medical Logistics NCOIC WI CERFP.

Headquarters, Department of the Army. *Army Regulation 11-34: The Army Respiratory Protection Program.* 25 JUL 2013.

Headquarters, Department of the Army. *Pamphlet 385-61: Toxic Chemical Agent Safety Standards*. 13 Nov 2012.

Hermanson, Jeff, JSGPM Program Manager, Avon Protection Systems.

Immediate Response Technologies. http://www.imresponse.com/.

Relitz, Scott, TSgt, 115FW LRS, Mobility/IPE.

United States Department of Labor, Occupational Safety & Health Administration. *29 CFR 1910.134 Respiratory Protection.* www.osha.gov. Accessed 28 Nov 2015.

United States Department of Labor, Occupational Safety & Health Administration. *CBRN Escape Respirators*. www.osha.gov. Accessed 28 Nov 2015.

United States Environmental Protection Agency. *Safety Zones*. http://www2.epa.gov/emergency-response/safety-zones. accessed 12 OCT 2015.

Watson, Roger, National Guard ComSupCen CBRNE Account Manager.